NUCLEAR WASTE TECHNICAL REVIEW BOARD
FULL BOARD MEETING

SUBJECT: CORROSION RESEARCH AND MODELING UPDATE

PRESENTER: DR. R. DANIEL McCRIGHT

PRESENTER'S TITLE AND ORGANIZATION: TECHNICAL AREA LEADER, ENGINEERED BARRIER MATERIALS CHARACTERIZATION MANAGEMENT AND OPERATING CONTRACTOR LAS VEGAS, NEVADA

TELEPHONE NUMBER: (510) 422-7051

LAS VEGAS, NEVADA
APRIL 19-20, 1995
Outline of Presentation

- Revised Scientific Investigation Plan (SIP)
  - Candidate Materials
  - Bounding Environments
- Status of Experimental Work
  - Types of Corrosion Tests
- Status of Performance Modeling
  - General Corrosion and Oxidation
  - Pitting Corrosion
- Brief Status of Other Activities
- Summary and Outlook
Container Materials Work Governed by a Scientific Investigation Plan (SIP)

- SIP is formal description of work to be performed
- Individual activities are 'graded' for determining quality assurance levels
- Most recent SIP (January 1995) covers work planned for next five years
- Activities grouped into four areas:
  - Degradation mode surveys and information bases
  - Corrosion testing and physical properties evaluation
  - Model development of performance behavior
  - Materials recommendations
Commentary on Planned Activities in the Metallic Barriers SIP

- Degradation mode surveys and information bases
  - Compile existing information as it applies to Yucca Mountain
  - Determine test needs
  - Engineered Materials Characterization Report and updates

- Corrosion testing and physical properties evaluation
  - Mostly laboratory-based in this design phase
  - "Anticipated" environments, "accelerated" test environments, and credible "what-if" scenarios
  - Abiotic and microbial testing environments
  - Base metal and weld metal tested and evaluated
  - Frequent dialogue with model development
  - May support some field tests
Commentary on Planned Activities in the Metallic Barriers SIP (cont’d)

• Model development for performance behavior
  – Organized by degradation mode
  – Determine important chemical, physical, metallurgical, mechanical parameters (Deterministic Models)
  – Evaluate stochastic factors (esp. forms of localized corrosion and stress corrosion - Deterministic and Probabilistic Models)
  – Describe performance as a “damage function”

• Materials recommendations
  – Establish selection criteria, weighting factors, ranking (conducted with other elements in the Project)
  – Provide additional specifications on selected materials (as needed)
  – Likely seek outside review of selection process
Sequence of Major Container Materials Activities

- Degradation Mode Surveys
- Corrosion Testing and Physical Evaluation
- Model Development
- Criteria
- Recommendations
- Selection

Time
Interfaces Between Engineered Barrier Materials Work and Other Efforts

- Near-Field Environment
  (includes Man-Made Materials)

  Waste Package Design
  Engineered Barrier Materials
  Performance Assessment

  Waste Form
Candidate Materials for Multiple Barrier Waste Package Containers

- Require several candidate materials because:
  
  - Different candidate materials for the different barriers (inner and outer barriers)
  
  - Possibly use different candidate materials for different waste package designs consistent with the expected "thermal load strategies"
# CANDIDATE CORROSION RESISTANT MATERIALS

<table>
<thead>
<tr>
<th>UNS Number</th>
<th>Commercial Name</th>
<th>ASTM Number</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>N08825</td>
<td>Alloy 825, Incoloy 825</td>
<td>B 424 (plate)</td>
<td>42% Ni, 21% Cr, 32% Fe, 3% Mo, 2% Cu, 1% Ti</td>
</tr>
<tr>
<td>N06985</td>
<td>Alloy G-3, Hastelloy G-3</td>
<td>B 581 (plate)</td>
<td>49% Ni, 22% Cr, 19% Fe, 7% Mo, 1% W</td>
</tr>
<tr>
<td>N06022</td>
<td>Alloy C-22, Hastelloy C-22</td>
<td>B 575 (plate)</td>
<td>58% Ni, 21% Cr, 13% Mo, 4% Fe, 3% W</td>
</tr>
<tr>
<td>N06455</td>
<td>Alloy C-4, Hastelloy C-4</td>
<td>B 575 (plate)</td>
<td>62% Ni, 16% Cr, 16% Mo, 3% Fe, 1% Ti</td>
</tr>
<tr>
<td>R53400</td>
<td>Titanium Grade 12</td>
<td>B 265 Grade 12 (plate)</td>
<td>“Lean alloy” containing 0.7% Ni, 0.3% Mo</td>
</tr>
<tr>
<td>new alloy</td>
<td>Titanium Grade 16</td>
<td>B 265 Grade 16 (plate)</td>
<td>“Lean alloy” with 0.05% Pd</td>
</tr>
</tbody>
</table>
# Candidate Corrosion Allowance Materials

## Carbon and Alloy Steels

<table>
<thead>
<tr>
<th>UNS No.</th>
<th>Commercial Name</th>
<th>ASTM No.</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>G10200</td>
<td>1020 wrought carbon steel</td>
<td>A 516 (grade 55)</td>
<td>0.22 max C, 0.6-1.2 Mn, 0.15-0.40 Si</td>
</tr>
<tr>
<td>J02501</td>
<td>centrifugally cast carbon steel</td>
<td>A 27 (grade 70-40)</td>
<td>0.20 max C, 1.40 max Mn, 0.8 max Si</td>
</tr>
<tr>
<td>K21590</td>
<td>2-1/4 Cr - 1 Mo alloy steel</td>
<td>A 387 (grade 22)</td>
<td>2.0-2.5 Cr, 0.9-1.1 Mo, 0.15 max C, 0.3-0.6 Mn, 0.5 max Si</td>
</tr>
</tbody>
</table>
# CANDIDATE "INTERMEDIATE" OR MODERATELY CORROSION RESISTANT MATERIALS

**Copper and Nickel Alloys**

<table>
<thead>
<tr>
<th>UNS Number</th>
<th>Commercial Name</th>
<th>ASTM Number</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>N04400</td>
<td>Alloy 400, Monel 400</td>
<td>B 127 (plate)</td>
<td>Ni-Cu alloy containing 67% Ni, 32% Cu, 1% Fe</td>
</tr>
<tr>
<td>C71500</td>
<td>70/30 Copper-Nickel, CDA 715</td>
<td>B 171 (plate)</td>
<td>Cu-Ni alloy containing 67% Cu, 31% Ni, 1% Fe</td>
</tr>
</tbody>
</table>
Interaction of Container Corrosion and Man-Made Materials Test Activities

- "Man-made", or "introduced" materials, may significantly influence chemistry of water contacting waste package container

- "Bounding" environments selected to account for changes in water chemistry due to:
  - Diesel fuels and other organics
  - Microbial metabolism
  - Concretes and grouts
"Bounding Environments"
Proposed for 5-Year Corrosion Tests

**Dilute Groundwater**
- like J-13
- base case

<table>
<thead>
<tr>
<th>Acidified Concentrated Groundwater</th>
<th>Concentrated Groundwater</th>
<th>Alkalized Concentrated Groundwater</th>
</tr>
</thead>
<tbody>
<tr>
<td>• pH as low as 2</td>
<td>• 20-100x J-13 ionic concentration</td>
<td>• pH as high as 12</td>
</tr>
<tr>
<td>• simulates extreme case of &quot;man made&quot; materials conditioning environment (diesel fuels, organics, sulfur containing comp'ds)</td>
<td>• simulates dry-out and resaturation of ionic species as temperature increases and decreases</td>
<td>• simulates water conditioning by concretes, grouts</td>
</tr>
<tr>
<td>• chemically simulates microbial metabolism</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Test at 60° and 90°C
- Test in liquid phase, in vapor phase over liquid (possible some specimens at water line)
Outline of Presentation

- Revised Scientific Investigation Plan (SIP)
  - Candidate Materials
  - Bounding Environments

⇒ Status of Experimental Work

⇒ Types of Corrosion Tests
- Status of Performance Modeling
  - General Corrosion and Oxidation
  - Pitting Corrosion
- Brief Status of Other Activities
- Summary and Outlook
Corrosion Testing Underway or Proposed for Near Future

- "Long term" (5-yr) "comprehensive" corrosion test
- Critical pitting and crevice corrosion potential determinations
- Corrosion tests under electrochemical control
- Thermogravimetric analysis (TGA) studies
- Fracture mechanics crack growth studies
- Microbiologically influenced corrosion (MIC) scoping studies
- Radiolytic effects on corrosion of container materials
- Studies on "basket" materials
INITIATION OF A 5-YEAR COMPREHENSIVE CORROSION TEST IS A HIGH PRIORITY

"MULTITUDE" OF SPECIMENS REQUIRED

- Candidate Materials
- Specimen Types
- Replicates
- Water Chemistries
- Temperatures
- Exposure Regions (Water, Vapor, Water-Line)
- Metallurgical Conditions (Base Metal, Weld)
- Evaluation Intervals

EACH PARAMETER IS MULTIPLICATIVE
Features of 5-year Comprehensive Corrosion Test

- Expose multitude of specimens of different materials and different geometries
  - flat coupons for weight loss, pitting, intergranular observation
  - creviced specimens
  - self-loaded specimens with and without welds for stress corrosion, hydrogen embrittlement
  - galvanically coupled sandwich specimens
- Withdraw specimens at periodic intervals
  - examine for attack pattern
  - quantify degradation
  - destructively examine some specimens
  - archive or replace specimens back in test cell for additional exposure
  - expose for 5 years or longer
Features of 5-year Comprehensive Corrosion Test (cont’d)

- Results will indicate
  - general corrosion rates
  - pitting corrosion attack (number pits, depth of attack, distribution of pits)
  - crevice corrosion attack (depth of attack, distribution of attack)
  - intergranular/selective attack (depth, pattern)
  - stress corrosion or hydrogen embrittlement (stress level, pattern, distribution)
  - galvanic attack or galvanic protection
Status of 5-Year Comprehensive Corrosion Test

- **Experimental Design**
  - 44 separate test cells, 800 liters each, required volume
  - 50% complete, internal design review on April 25, 1995

- **Laboratory Refurbishment**
  - Large dedicated laboratory required
  - Carpentry and painting completed
  - Major electrical and plumbing work begun

- **Procurements**
  - Order for 12,000 corrosion test specimens (weight loss, crevice, U-bends being competitively bid)
  - Order for galvanic corrosion specimens being assembled

- **Near-Term Future Plans**
  - Complete design by May 15
  - Release all procurements by May 31
Measurements of “Critical” Potentials Indicate Localized Corrosion Susceptibility

- “Passive Film Breakdown Potential” and the “Repassivation Potential” determined by electrochemical techniques
- Position of these two critical potentials relative to corrosion potential indicates susceptibility to pitting corrosion and crevice corrosion
- Individual determinations performed in 1-2 days; supplements results of “5-yr” comprehensive corrosion test
- Large number of responses obtained for alloy/environment combinations
- Tests performed over wide range of chemical and metallurgical parameters, e.g., pH, T, Cl⁻, SO₄²⁻, NO₃⁻, F⁻, Fe³⁺, Cu²⁺, “heat to heat” variations in the alloy, and so on -- Determine single and combined effects of variables
Corrosion Testing Under Electrochemical Control

• Conduct tests maintained at constant applied potentials for longer term check of "critical potential" determinations
  – Provides important input parameters to model development
  – Experimental validation of model predictions
• Conduct companion tests to 5-yr comprehensive corrosion test to determine any changes of corrosion potentials with time
• Most electrochemical tests will run for a few weeks, but selected number will run much longer
Thermogravimetric Analyzer Apparatus

- Microbalance Chamber
- He purge
- Constant Temperature Bath
- Humidity Sensor
- Constant Temperature Bath
- Test Specimen
- Reaction zone
- Dry Air
- Reaction gas inlet (heated)
- Humid Air (heated)
- Computer Controlled
  - Data Acquisition
  - Temperature control
  - Flow control
Thermogravimetric Analysis Studies

- Determine the temperature-humidity regions where there is susceptibility to thin-film aqueous (electrochemical) corrosion

- Results of studies will be used to select conditions for longer-term testing

- Thin-film aqueous corrosion is also dependent on:
  - susceptibility of metal
  - gaseous species (O₂, H₂S, CO₂, NOₓ, others)
  - surface condition (roughness, corrosion product)
  - hygroscopic species on surface (e.g., NaCl, CaCO₃)

- Thermogravimetric analyzer
  - 50 - 110°C (custom designed temperature control)
  - in-situ humidity & temperature measurement
  - 50 µg resolution
  - computer control / data acquisition
Thermogravimetric Analysis Studies (cont'd)

• Previous studies of thin film water corrosion
  - ambient conditions
  - periodic wet / dry conditions (accelerates corrosion)

• Elevated temperature studies (50 - 110°C)
  - not extensively studied
  - reaction rate acceleration with temperature
  - effect of temperature on corrosiveness of gases
  - oxygen solubility decrease with temperature
  - stability of corrosion product form (change in microstructure with temperature of formation)

• Initial studies will emphasize carbon steel and copper-base materials
Background for fracture mechanics

- Design goal - operate below $K_{ISC}=0$

- Stress intensity to start a corrosion crack

- Crack velocity $\frac{da}{dt}$ [log scale]

- Nominal stress

- Magnitude of stress along $x$ axis, $\sigma_y$

- Crack tip

- Stress intensity, $K_I = \sigma \sqrt{\pi a} f$ [geometry]

- Load ratio $R = \frac{K_{MIN}}{K_{MAX}}$
Results from Fracture Mechanics
Stress Corrosion Crack Growth Measurements

- Currently testing Alloys 825, C-4, C-22, Ti Grade 12 in 93°C simulated J-13 water, $K_{\text{max}} = 26 - 41 \text{ MPa} \cdot \text{m}^{-3/2}$, $R = 0.5$ and 0.7
- Crack growth rates $< 10^{-11} \text{ m/sec}$
- Crack growth rates indicative of highly stress corrosion resistant material
- Will continue these tests, change $K_{\text{max}}$ and $R$ to generate full crack velocity vs. stress intensity curve
- Will add other environments and temperatures (especially toward more aggressive conditions)
- Considering additional kinds of stress corrosion tests to supplement these tests
## Impact of Microbiologically Influenced Corrosion (MIC)

<table>
<thead>
<tr>
<th>Candidate Material</th>
<th>Susceptibility*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Steel</td>
<td>Many kinds of bacteria, both aerobic and anaerobic, attack steels, resulting in enhanced general corrosion, pitting, and hydrogen embrittlement (many studies)</td>
</tr>
<tr>
<td>70/30 Copper Nickel</td>
<td>Sulfate reducing bacteria caused pitting. Acid Polysaccharides increased corrosion (several studies)</td>
</tr>
<tr>
<td>Monel 400</td>
<td>Sulfate reducing bacteria caused deep pitting, intergranular attack (several studies)</td>
</tr>
</tbody>
</table>

* Summarized from G. Geesey, "A review of the potential for microbially influenced corrosion of high-level nuclear waste containers" CNWRA 93-014 (June, 1993)
**Impact of Microbiologically Influenced Corrosion (MIC) (cont.)**

<table>
<thead>
<tr>
<th><strong>Candidate Material</strong></th>
<th><strong>Susceptibility</strong>*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incoloy 825</td>
<td>Sulfate reducing bacteria caused pitting and crevice attack in lake water and sea water (2 studies)</td>
</tr>
<tr>
<td>Hastelloy C-4, C-22</td>
<td>Appears to be immune, but pure Ni is attacked</td>
</tr>
<tr>
<td>Titanium</td>
<td>Appears to be immune</td>
</tr>
</tbody>
</table>

* Summarized from G. Geesey, "A review of the potential for microbially influenced corrosion of high-level nuclear waste containers" CNWRA 93-014 (June, 1993)
Plans for MIC Evaluation and Testing

- Workshop on Microbial Activity at Yucca Mountain (YM) held April 1995
- Plan to evaluate YM repository site for presence of microbial species known to enhance corrosion of candidate container materials
  - native microbial populations
  - microbes associated with introduction of “man made” materials into repository
  - consortriums of microbial populations
  - moisture films initiating aqueous corrosion also act as biofilms
- Plan to conduct experimental measurements of corrosion in controlled environments, as suggested from above evaluations
  - Compare results with those obtained under “abiotic” but chemically simulated conditions
Radiolytic Effects on Corrosion

- Penetration of gamma radiation through container wall causes chemical changes (radiolysis) in environment that may enhance corrosion (e.g. O₂, H₂O₂, NOₓ, H₂)
- Readily calculate gamma field attenuation through metal
- Need to determine radiolytic-induced corrosion changes as function of gamma dose rate to determine threshold
  - Limit of discernible corrosion attack
  - Changes in corrosion potential
  - Analytical determination of radiolysis products
- Plan to start late FY-95, early FY-96; emphasis on carbon steel and Cu/Ni alloys
Corrosion Studies on “Basket” Materials

- SIP on Basket Materials completed and approved
- Experiments planned to evaluate expected long-term chemical environments
- Experiments planned to study short-term corrosion behavior to screen candidate materials
  - Structural candidates: Al, Cu, Stainless Steel, 702 Zr, ceramics
  - Neutron absorbers: B (in Al, Cu, SS), Hf in 702 Zr, Gd and other lanthanides in the ceramics
- Long-term corrosion testing of promising candidates will follow
Outline of Presentation

- Revised Scientific Investigation Plan (SIP)
  - Candidate Materials
  - Bounding Environments
- Status of Experimental Work
  - Types of Corrosion Tests

⇒ Status of Performance Modeling
⇒ General Corrosion and Oxidation
⇒ Pitting Corrosion

- Brief Status of Other Activities
- Summary and Outlook
## Types of Models Depend on Degradation Phenomenon

<table>
<thead>
<tr>
<th>PHENOMENON</th>
<th>MODEL TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Temperature Oxidation</td>
<td>Deterministic</td>
</tr>
<tr>
<td>General Aqueous Corrosion</td>
<td>Deterministic</td>
</tr>
<tr>
<td>Intergranular Corrosion</td>
<td>Deterministic</td>
</tr>
<tr>
<td>Pitting Corrosion</td>
<td>Deterministic and Probabilistic</td>
</tr>
<tr>
<td>Crevice Corrosion</td>
<td>Deterministic and Probabilistic</td>
</tr>
<tr>
<td>Stress Corrosion Cracking</td>
<td>Deterministic and Probabilistic</td>
</tr>
<tr>
<td>Hydrogen Embrittlement</td>
<td>Deterministic and Probabilistic</td>
</tr>
<tr>
<td>Phase Instability</td>
<td>Deterministic and Probabilistic</td>
</tr>
</tbody>
</table>
Deterministic Models for Oxidation and General Corrosion of Steels

- Parametric correlation calculated from available literature data, where \( x \) = depth; \( t \) = time; \( T \) = temperature:
  - **Dry Oxidation:** \( x = 1.79 \times 10^5 t^{0.33} \exp[-6870/T]^* \)
    - derived from data obtained at somewhat higher temperature regime; implies a "cubic" growth law
  - **Aqueous Corrosion:** \( x = 2.52 \times 10^6 t^{0.47} \exp[-2850/T]^* \)
    - applies to near neutral pH, air saturated water, implies a "parabolic" oxide film growth
  - **Wastage of material heavily dependent on "thermal load" and projection of temperature decay**

Estimates of Wastage of Steel Containers

- Penetration due to dry oxidation is negligible regardless of thermal load (a few \( \mu \text{m}/10^5 \text{ yrs} \)); therefore penetration for high thermal load case is quite small
- Transition from “dry” to “wet” conditions occurs at 60% relative humidity
- Penetration due to aqueous corrosion dependent on thermal load
- Estimate of 20 mm penetration in 5000 yrs., 40 mm penetration in 100,000 yrs. for low thermal load repository (somewhat higher rates at repository periphery)
- However, corrosion rates much higher if exponent on time increases (corrosion products spall off) or if water chemistry becomes more aggressive (e.g. microbial activity) -- experimental work to address these concerns
Modeling Pitting Initiation and Growth

- Develop model that incorporates probabilities of initiation, growth, and death of pits for candidate corrosion resistant materials (Ni-base, Ti-base alloys)
- Confirm model with experimental data to be obtained from electrochemical tests and 5-year comprehensive corrosion test
- Work collaboratively with Performance Assessment to input model for container performance
• Microscopic fluctuations in local conditions cause local film breakdown.

Pit generation
("birth", \( \lambda \))

Pit repassivation
("death", \( \mu \))

Aqueous Solution

Passive Film

Metal

No Pit

Unstable Pit

Stable Pit

Critical age, \( \tau_c \)

Death

Induction time, \( \tau_{\text{ind}} \)

Time

Definitions used in the Pitting Corrosion Model

- Embryo “birth” (λ) corresponds to the localized breakdown of the passive film
- Embryo “death” (μ) corresponds to repassivation of the metal
- The critical age (τ_c) required for stable pit formation is related to the ratio of the minimum stable pit depth to the velocity of embryo growth
- The pit growth probability (γ) may be related to a succession of death and renucleation events or that some pits grow at the expense of others
Simulation of Induction Time Distribution

Data of Shibata

- 304 SS / (6/0 polish)
- 3.5% NaCl, 35 °C
- $E = 0.35 \text{ V}$

- Total specimens: 72
- 7 specimens with no pit

Monte Carlo Simulation

- $\lambda = 0.02$
- $\mu = 0.3$
- $\tau_c = 15$
- $N = 400$

- Total simulations: 75
- 3 simulations with no pit
Pitting Corrosion "Damage Function"

- Provides time to first penetration of container
- Provides number of pits penetrating container as a function of time
Experimentally Determined Damage Functions

- Alcan 2S-O Aluminum
- 20 °C Tap Water
- Data of Nathan and Dulaney

- Goal is to qualitatively simulate:
  1. Number of small pits decreases with exposure time.
  2. Peak at intermediate depths.
  3. Peak moves to larger depths as exposure time increases.
  4. Height of peak decreases as exposure time increases.
  5. At long times, the distribution is skewed toward small pits.
Simulated Pit Depth Distributions

- Exponential decay in pit "birth" probability with time
- Stochastic pit growth
Modeling the Effects of Environment on Pitting

- Modeling environmental effects required for:
  - Extrapolating "accelerated" test data to longer times and less aggressive environments
  - Exploring various environmental scenarios
- For the stochastic model this means determining:
  - (1) birth probability, (2) death probability, (3) critical age, (4) pit growth probability
- A first attempt was made using simple phenomenological expressions that are physically reasonable
  - Included variables of (1) potential, (2) temperature, (3) chloride ion concentration and their assumed variation with time
  - These three variables interact on the four pitting model parameters in a fairly complex way
  - Illustrative model shown in next few viewgraphs
Experimental Input to Support Pitting Model is Essential

- Combination of electrochemical and microscopic techniques to identify the “four” model parameters
- Conduct experiments over range of electrochemical potential (above and below the “critical potentials” for passive film breakdown and repassivation)
- Conduct experiments over range of physical, chemical, metallurgical parameters (temperature, electrolyte chemistry, pH, metal microstructure, and so on)
- Note that many of the same experiments are useful for alloy screening/selection
Outline of Presentation

- Revised Scientific Investigation Plan (SIP)
  - Candidate Materials
  - Bounding Environments
- Status of Experimental Work
  - Types of Corrosion Tests
- Status of Performance Modeling
  - General Corrosion and Oxidation
  - Pitting Corrosion

⇒ Brief Status of Other Activities
⇒ Summary and Outlook
Degradation Mode Surveys (DMS) and Information Bases -- Brief Status

- Recently completed DMS on Titanium and Ti-base alloys (Jan. 1995)
- DMS on remainder of Ni-base candidate materials; DMS on welding microstructures in progress
- DMS on galvanic effects planned
Commentary on Materials
Recommendations for Multiple Barrier Waste Package Containers

- Long material endurance is most important consideration
- Materials/fabrication processes limited to reasonably available technology
- Moderate strength materials are adequate
- Predictability of performance is important in selecting materials
- Uncertainty in environment changes over long time periods forces design/materials conservatism
- Revisit selection process used for SCP-CD materials
- Likely retain same selection criteria, but likely change weighting factors (different factors for inner and outer barriers, for “high” thermal load vs. “low” thermal load configurations)
In Summary

- Scientific Investigation Plan (SIP) prepared, reviewed, and approved for Metallic Barriers work
- Candidate materials and bounding test environments described
- Experimental work is underway
  - Oxidation/corrosion transition
  - Fracture mechanics stress corrosion cracking
  - Construction of 5-year comprehensive corrosion test
- Experimental activity planned for near future
  - Electrochemical testing for localized corrosion
  - Microbiologically influenced corrosion scoping studies
  - Threshold for radiolytic corrosion
In Summary (cont'd)

- Model development begun
  - Low temperature oxidation and general aqueous corrosion
  - Pitting corrosion initiation and growth (stochastic features)
- Additional modeling efforts planned for near future
  - Introduction of effects of experimental parameters into pitting corrosion model
  - Extension of pitting model to other corrosion modes with stochastic features (crevice corrosion, stress corrosion)
- Efforts continue on completing degradation mode surveys and updating Engineering Materials Characterization Report
- Progress made on developing methodology for materials selection
Outlook

- High level of experimental activity forecast for next few years
  - Provides important basis for materials recommendations
  - Provides much input for performance models
- Expectation of greater effort in model development as test results become available
- Increasing interaction with other program elements essential for success
- Metallic Barriers SIP describes proposed work in considerable detail
  - “Plan your work; then, work your plan”